SOLID ROCKET PLANT

TWENTIETH MONTHLY PROGRESS REPORT

ALGOL SOLID ROCKET MOTOR PROGRAM

Contract No. NAS 1-1330

Period Covered: January 1963

Report 0498 01M 20 February 1963

AEROJET GENERAL TIRE GENERAL

AEROJET-GENERAL CORPORATION

SACRAMENTO, CALIFORNIA

February 1963

Report 0498-01M-20

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Prepared for

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
LANGLEY RESEARCH CENTER
Langley Field, Virginia

AEROJET-GENERAL CORPORATION
A SUBSIDIARY OF THE GENERAL TIRE & RUBBER COMPANY

PREFACE

This report was prepared by M. C. Huisking, Engineering Project Assistant, and edited by Doris Hollister.

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FIGURE LIST

I. INTRODUCTION

This is the twentieth monthly progress report to the National Aeronautics and Space Administration (NASA) under Contract NAS 1-1330. This report covers the fabrication, testing, and delivery of Algol solid rocket motors for the Scout vehicle. The program has undergone numerous redirections since it was initiated; a summary of the program history is as follows:

PROGRAM MILESTONES

Date	Event
June 1961	The Algol I phase of the program was established with the receipt of a letter of intent covering 17 Algol I motors: 16 delivery motors and one motor for static firing.
November 1961	Direction was received for the development of a new motor (designated Algol IIA) and the reduction of the number of motors in the existing Algol I phase.
January 1962	Ammendment to the contract was received that reduced the number of Algol I motors to nine. The original Algol II phase consisted of the design, development, and testing of 14 Algol IIA motors: ten delivery motors and four motors for static firings; delivery of three Algol Dual Transporters; and tooling for processing four units per month.
February 1962	Contract negotiations were completed on scope of work defined in January.
April 1962	Contract change notice (CCN) 1 was received for the fabrication and delivery of two borescopes.
June 1962	A contract was negotiated for a follow-on order for the delivery of 13 additional Algol IIA motors.
November 1962	Direction was received to reduce the Algol IIA motor delivery rate from four to two units per month, which extended the delivery schedule by 6 months.
December 1962	Authority was received to proceed with rehabilitating the Algol IIA-3 chamber for an additional (fifth) static test.
January 1963	Direction was received for the fifth static test to be conducted as proposed with the Algol IIA-3 rehabilitated chamber.

I. Introduction (cont.)

The Algol I phase of the program was completed in May 1962 and descriptions of this past effort are no longer reported.

The schedule for the Algol IIA program (Figure 1) shows the reduction in the delivery rate for Algol IIA motors from four to two units per month in compliance with the direction received in November 1962. Also scheduled, in accordance with the direction received in January, 1963, is the fifth firing, that of the rehabilitated IIA-3 motor, IIA-3 (Rehab). The firing is scheduled for February 25.

II. SUMMARY

The production schedule was accelerated during the month of January to compensate for the delay in December caused by the difficulty in obtaining a suitable hard core. Motors SN 15, 16, 17, and 18 were all cast in January and the production effort is now back on schedule. The IIA-3 rehabilitated chamber was originally scheduled to be completed by 7 January 1963, but, because of insulation problems, was not completed until 31 January 1963. The casting date was therefore not met and motor SN IIA-18 was cast in its place. Motor IIA-3 (Rehab) will be cast the second week in February 1963, and the firing was postponed from 16 to 25 February 1963.

Motor IIA-13 is ready to be radiographically inspected and delivered as soon as the nozzle is installed. Motors IIA-14 and -15 will be sent to Naval Ammunition Depot (NAD) Concord, Calif., for radiographic inspection. Motors IIA-16 and -17 are in process.

Laboratory and subscale-motor firing data are being collected for the burning-rate study being conducted concurrently with the development program. These data will be compared with flight-test data when available.

II. Summary (cont.)

An igniter-squib test program is also being conducted as a result of a recent investigation of the entire Scout ignition system.

III. PROGRAM STATUS

A. DESIGN

The basic development phase of the program was completed with the fourth static firing. The last two motors were of flight configuration, and data from these tests demonstrated the effectiveness of the design; consequently, the design of the major components has been established. A final (fifth) motor will be fired to confirm motor ballistics, acceptability of the aluminum core, and qualification of a second-source nozzle from CTL, Santa Ana, Calif.

A comprehensive study of motor performance variations and predictability will be submitted as a separate report. Information compiled to date on fabrication variations in motor hardware and propellant processing variations is showing good correlation for the somewhat limited data available. As the number of motors processed, fired, and/or launched increases, these data will be supplemented and will be useful for predicting Scout-vehicle performance.

A summary of motor weights of all Algol IIA motors produced to date is presented in Figure 2.

B. FABRICATION

The chambers for the follow-on order (13 motors) are being fabricated. The insulated chamber for Algol IIA-22 has been received, bringing the total insulated chambers received to nine. The nozzle fabrication for the follow-on order is proceeding and the first three nozzles were received in November; four additional units were received in January, bringing the total received to seven.

III. B, Fabrication (cont.)

The authority to proceed with the processing of the Algol IIA-3 rehabilitated chamber was received on 4 December 1962. This chamber was immediately shipped to Cell-Bell Chemical Company for cleaning and to Kerr Products for insulating. The insulating of this chamber was delayed because the aft opening of the chamber was found to be .015 in. too small to accommodate the existing aft layup tool. Therefore, it was necessary to fabricate a temporary tool that has an adjustable ring. This tool can be used on future chambers that might have a similar discrepancy. This insulation delay caused the firing date of the fifth static test to be slipped to 25 February 1963.

C. MOTOR PROCESSING AND SHIPPING

1. Motor Processing

Processing of the Algol IIA motor was affected by a NASA directive, TWX 337-338, S. T. Butler to C. W. Parr--Subject: Radiographic Inspection--Dated 30 August 1962. This directive added the requirement to the contract that all deliverable motors be inspected with either a borescope or radiograph. Motors IIA-4 through -9 were processed with Styrofoam star points imbedded in the grain. These Styrofoam inserts were originally used to change the configuration of the temporary wood cores for a grain-design modification. Because adequate release agents are unavailable, these inserts are not released from the propellant and become an integral part of the motor. The presence of the Styrofoam in the bore of the grain physically obstructs the use of a borescope for inspecting the motor interior. After several attempts, the Styrofoam was mechanically removed from motors IIA-6 and -7. Motor IIA-7 was borescopically inspected in conjunction with the borescope training program conducted by Aerojet-General for NASA personnel.

III. C. Motor Processing and Shipping (cont.)

Wood inserts were used in motors IIA-10, -11, -12, and -13 and without any complications. An aluminum hard core was used in casting all subsequent motors. The following summary of the status of the motors includes two Phase I motors, Algol ID-33 and -34:

Motor	Status	Grain Status	Inspection Status
IIA-13	Nozzle to be installed	Wood insert, removed	To be radiographically inspected at NAD
IIA-14	To be delivered	Aluminum hard core, removed	To be radiographically inspected at NAD
IIA-15	To be delivered	Aluminum hard core, removed	To be radiographically inspected at NAD
IIA-16	In final assembly	Aluminum hard core, removed	To be radiographically inspected at NAD
IIA-17	Being cured	Aluminum hard core	To be radiographically inspected at NAD
IIA-18	Being cast	Aluminum hard core	To be radiographically inspected at NAD
ID-33	In storage	Steel core, removed	No radiographic inspection required
ID-34	In storage	Steel core, removed	No radiographic inspection required

2. Shipping

Algol IIA Government-furnished equipment (GFE) now in storage at Aerojet-General consists of the following:

Item	Serial No.
Dual transporter	ATT-2
Dual transporter	ATT-3
Transtainer(1)	T-10
Transtainer(1)	T-13
Transtainer(1)	T-1

III. C, Motor Processing and Shipping (cont.)

Item	Serial No.
APU (temperature control)(1, 2)	109B621179/109B621181
APU (temperature control)(1, 2)	40C634807/40C634808
APU (temperature control)(1, 2)	40C634797/40C634810
APU (temperature control)(2)	40C634798/40C634812
APU (temperature control)(2)	70C639496/70C636879

(1) Reference Dwg 0-320359

(2) Does not include tie-down chain

D. IGNITER SQUIB TEST PROGRAM

A recent intensive investigation of the entire Scout ignition system included an investigation of the Algol IIA igniter. As a part of this investigation, information concerning the Algol IIA squib performance characteristics was requested. Data on some of the performance characteristics was submitted by technical letter to NASA. Also included were details of a squib testing program to be sponsored jointly by NASA Contracts NAS 1-1330 and NAS 9-456 to preclude duplication of effort. Concurrence in the program has not yet been received; however, the effort has continued and the tests to which the squibs will be subjected have been established. The Squib Acceptance-plan Flow Chart is shown in Figure 3. The following tests will be conducted:

1. Parr-Bomb Heat Output

The heat output will be measured by using samples of the squib-charge composition, i.e., (a) Holex ignition primer mixture; (b) AGC-furnished ignition powder; (c) AGC-furnished pyrotechnic powder only. The composition standards will be based on the results of the first lot. All subsequent lots of composition will be accepted on the basis of the initial-lot test results.

III, D. Igniter Squib Test Program (cont.)

2. Radiflo Test

Radiflo-test all squibs. Units showing leakage will be rejected.

3. No-Fire- and Minimum-Fire Currents Characteristics

An experiment based on Bruceton analysis, centered about the 1-amp, 1-watt, 5-min no-fire condition, will be performed.

Amperage will be the variable. Each unit will be tested on one bridgewire only, allowing the unfired units to be used for further testing, with the second bridgewire. The results will determine the distribution of the no-fire amperage. The lot shall be rejected if the .999 no-fire reliability at the 95% confidence level falls below 1.0 amp. This test will also give the distribution of the minimum firing current.

a. Sample size = 40 units
b. Unfired units left for further testing = 20 (approximately)
c. Fire all units at sea-level conditions, at 110°F
d. All units fired in a 1.0-in.^{3} volume chamber

4. Functioning-Time Variance

An experiment based on Bruceton analysis, to determine the functioning time at the recommended amperage, will be performed. The amperage will remain constant and the duration of application will be varied. Each unit will be tested on one bridgewire only, allowing the unfired units to be used for further testing. Results of the test will determine the distribution of the functioning time.

III, D, Igniter Squib Test Program (cont.)

The lot shall be rejected if the variance about the average exceeds ± .003 milliseconds at a reliability of .999 and a confidence level of 95%. The average will be established with the first lot of squibs accepted. All future lots must have the same average.

a. Sample size = 40 units
b. Unfired units left for further testing = 20 (approximately)
c. Fire units at altitude conditions, at 30°F
d. All units fired in a 1.0-in.^{3} volume chamber

5. Functioning-Time Curve

The functioning-time curve will be determined by firing four squibs at each of the following: X-amps, 2X amps, 4X amps, 8X amps, and 16X amps, where X is the raise-to-fire amperage as determined in the Bruceton analysis of the no-fire characteristics.

6. Drop Test

Twelve units (of random orientation) will be subjected to a 6-ft drop test and fired in a 1.0-in.^{3} volume chamber at sea level and recommended firing current. This test is for information only and will not be used for accept-reject criteria.

7. Autoignition

Eight units will be fired at 350°F for 8 hr in a 1.0-in.^{3} volume chamber at sea level and recommended firing current. This test is for information only and will not be used for accept-reject criteria.

III, D, Igniter Squib Test Program (cont.)

8. Pressure Test

Pressure-test all fired units (100) to 2000 psig at 350°F for 2 min. The lot shall be rejected if any units show leakage.

E. TOOLING

The tooling schedule is shown in Figure 4. The third aluminum hard core was received and inspected. Inspection revealed surface irregularities and dimensional discrepancies; consequently, the core was returned to the vendor for rework. Receipt of this reworked core is expected the first week of February.

IV. FUTURE WORK

A. Processing of delivery motors will continue during February. Algol motors IIA-13 through -16 will be shipped to Naval Ammunition Depot, Concord, Calif. for radiographic inspection. After inspection, the units will be shipped to their final destinations.

B. The reworked third hard core will be received.

C. Fabrication required for the follow-on order of 15 sets of inert parts will continue.

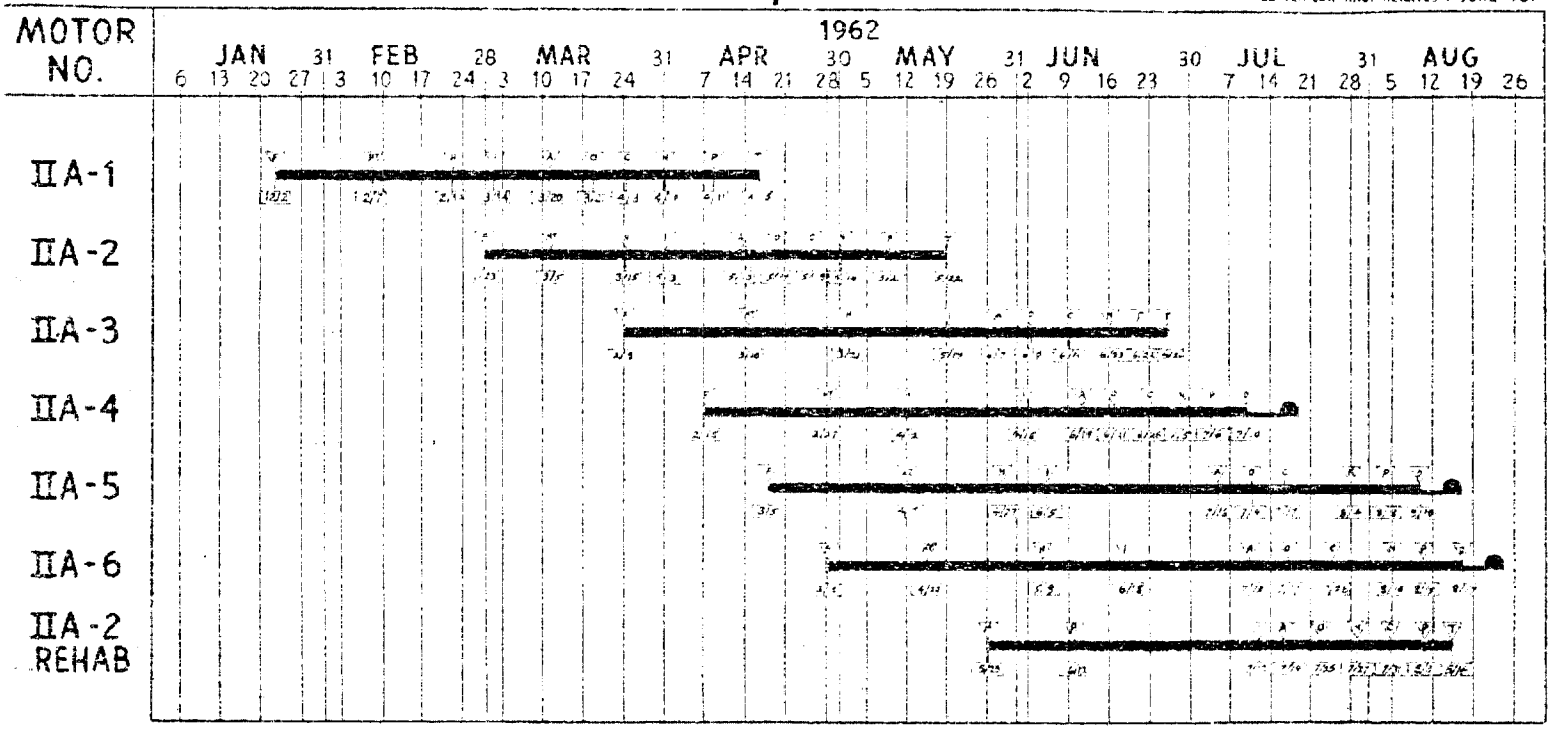
D. The refurbished Algol IIA-3 motor, designated IIA-3 (Rehab), is scheduled to be statically fired at ambient temperature on 25 February 1963. Following the firing, preliminary ballistic, thermal, and jet-vane-force data will be reduced and forwarded to NASA for review.

ALGOL II A

NAS-1-1330

MOTOR PRODUCTION/DELIVERY SCHEDULE

SCHEDULE REVISION "E" NOV 1962
LETTER CONTRACT RECEIVED 7 JUNE 1961



F START FABRICATION CHAMBER
HT HEAT TREAT
H HYDROTEST
R REHABILITATE CHAMBER
I INSULATE CHAMBER
A RECEIVE, ABRADE AND LINE
O CAST PROPELLANT
C CURE PROPELLANT
N RECEIVE NOZZLE
P FINAL ASSEMBLY
D FINAL INSPECTION AND SHIPMENT, F.O.B. NIMBUS, CALIF.
T TEST FIRE (A.G.C. SACRAMENTO)
▽ SCHEDULED TASK COMPLETION DATE
[DATE] ACTUAL DATE TASK COMPLETED
---- REVIEW DATE— ● FLOWN(SUCCESS)

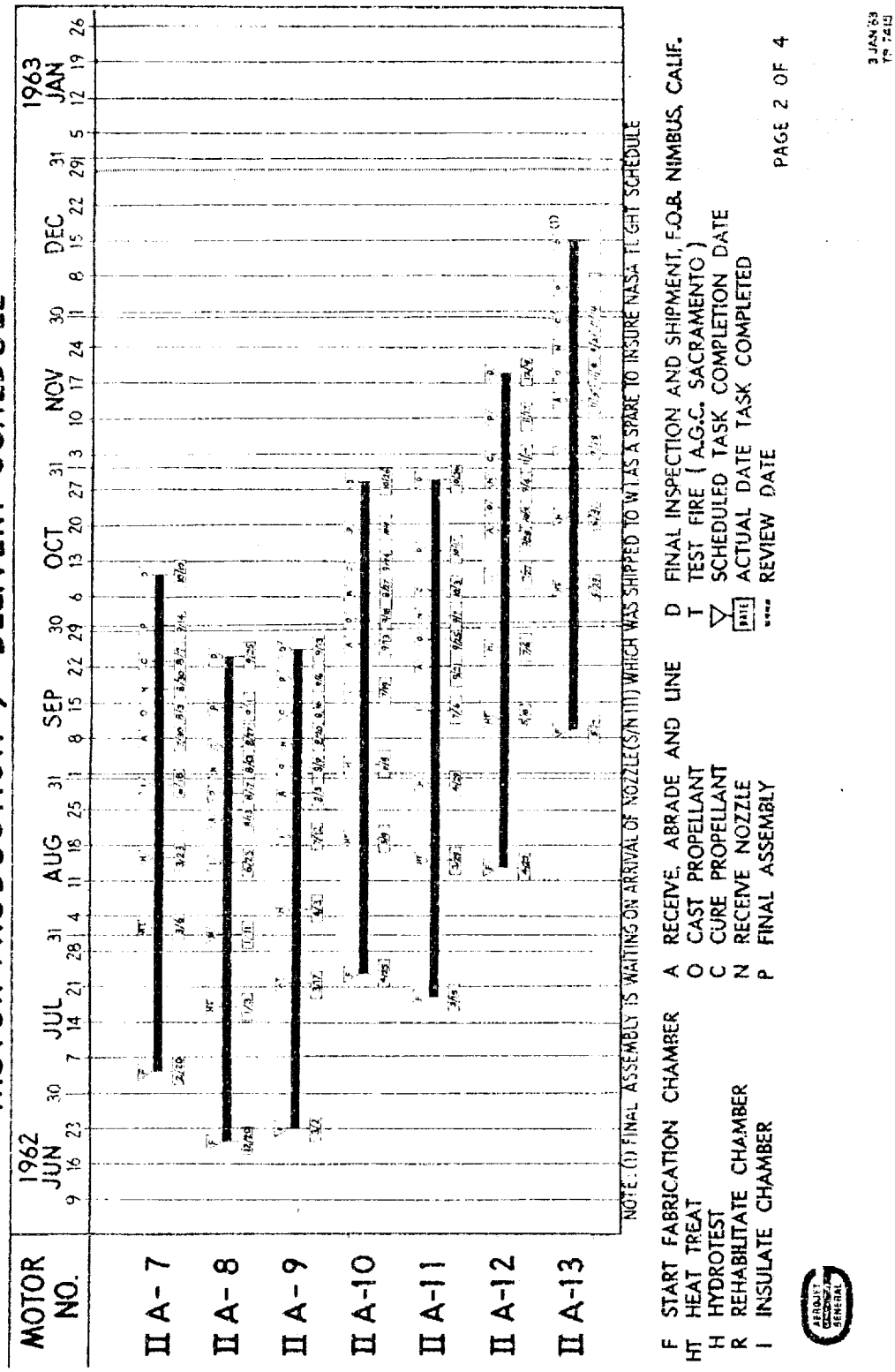
PAGE 1 OF 4

AEROJET GENERAL

TP 7415
4 JAN 63

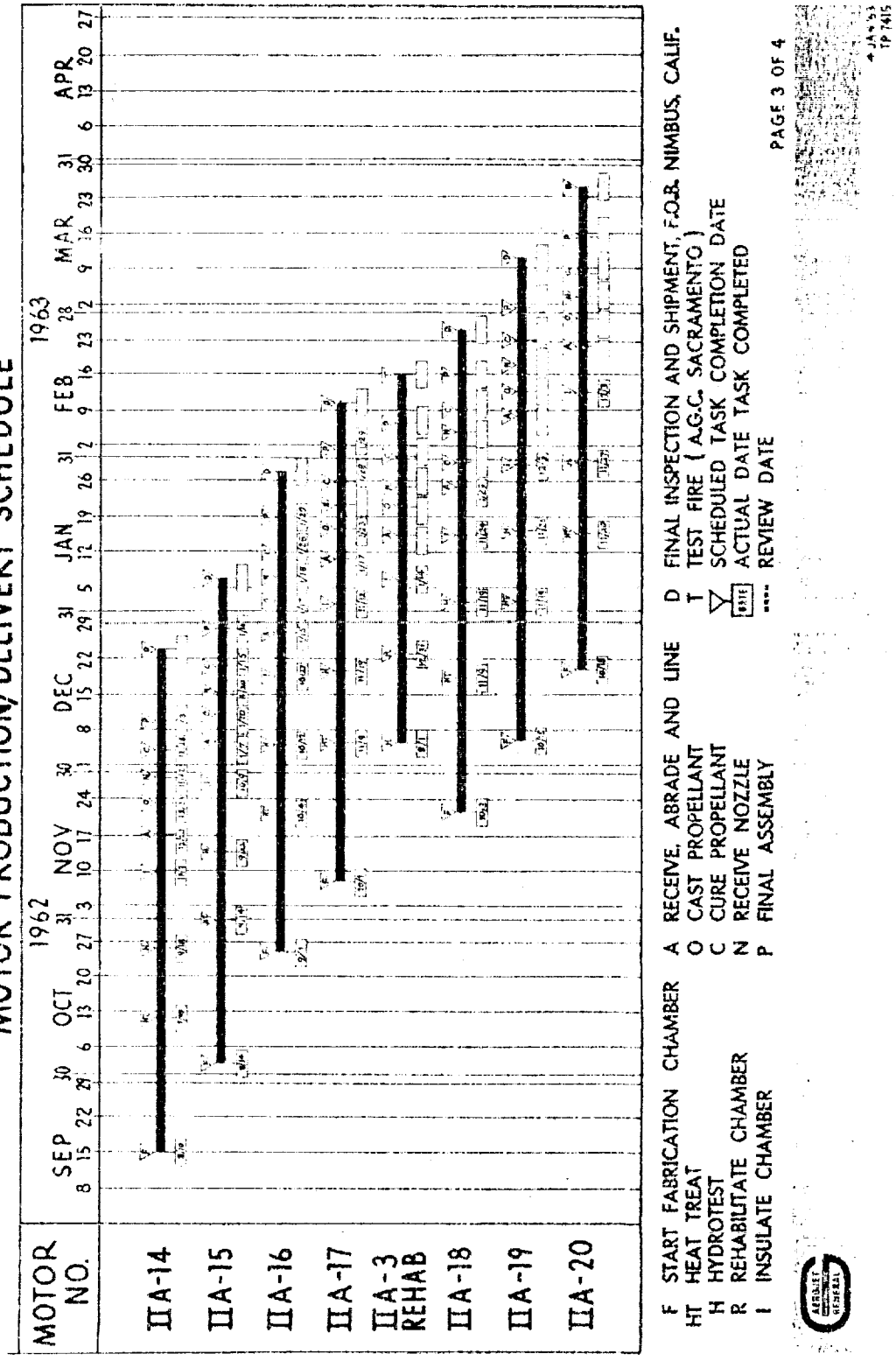
Figure 1, Sheet 1 of 4

Program Schedule, Algol IIA

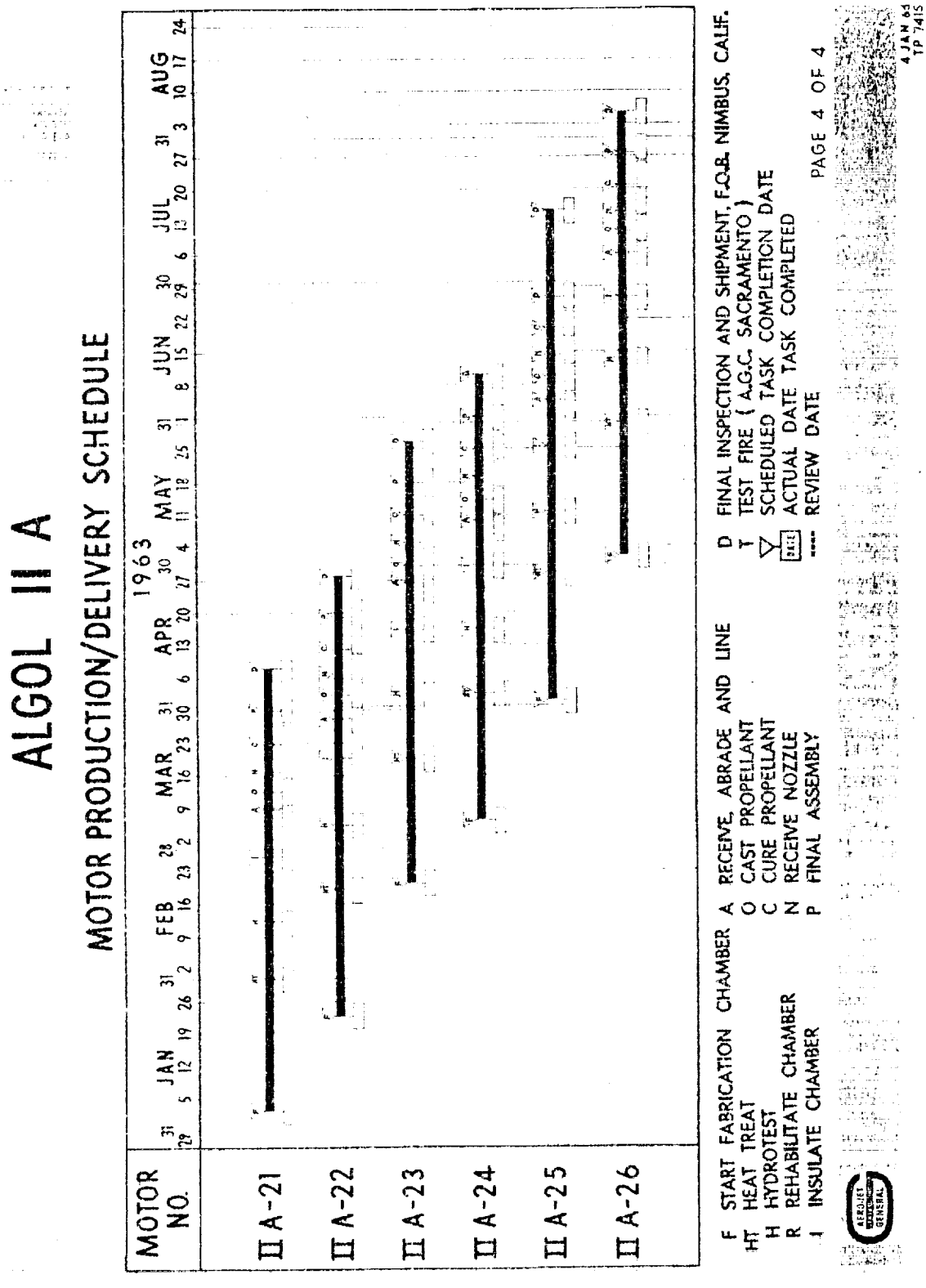


Program Schedule, Algol IIA

Figure 1, Sheet 2 of 4



Program Schedule, Algol IIA



Program Schedule, Algol IIA

Figure 1, Sheet 4 of 4

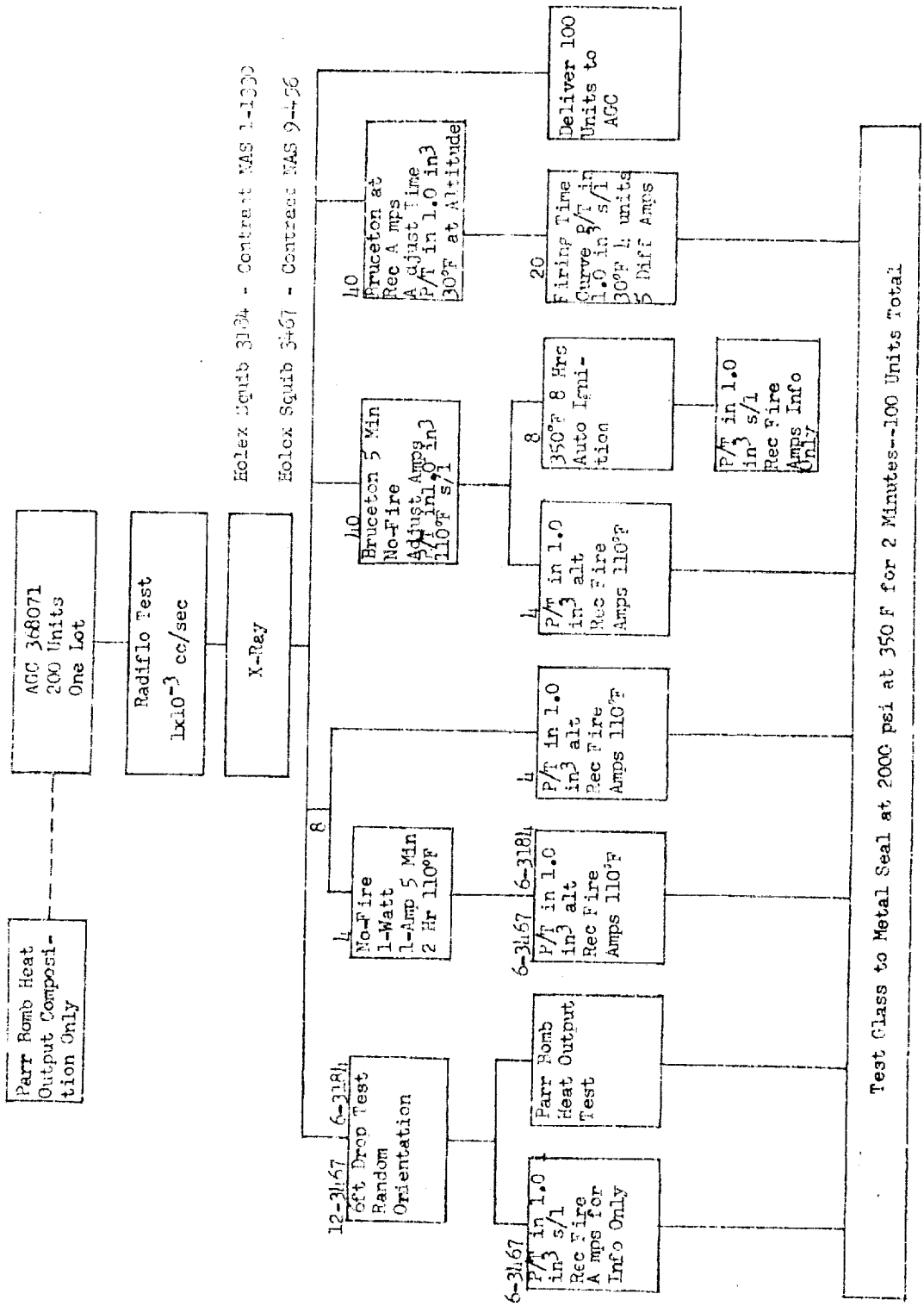
Motor No.	IIA-1(4)	IIA-2(5)	IIA-3	IIA-2R	IIA-4	IIA-5	IIA-6	IIA-7	IIA-8	IIA-9	IIA-10	IIA-11	IIA-12	IIA-13(8)	IIA-14	IIA-15	Average (6)	One Std. Dev.
Chamber S/N	673181	617662	617664	617662	617663	617665	617666	673184	673178	673185	617667	673185	617668	617671	[illegible]	6990[illegible]	-	-
Nozzle S/N	101	102	103	105	106	104	108	109	110	107	112	113	114		[illegible]	633052	-	-
Loaded Motor Wt., lb(1)	23774*	23656	23691	23615	23613	23641	23619	23588	23631	23561	23591	23610	23545(7)		[illegible]	23650	23617	40
Loaded Motor C. G. (2)	—	—	—	—	156.88	156.34	156.50	156.29	157.01	156.55	156.61	156.55	156.81		[illegible]	156.66	156.65	0.23
Fired Motor Wt., lb (1)	2174	2193	2167	2156	—	—	—	—	—	—	—	—	—		—	—	—	—
Fired Motor C.G. (2)	189.88	187.80	189.48	190.74	—	—	—	—	—	—	—	—	—		-	—	—	—
Grain Wt., lb (3)	21320*	21178	21225	21186	21177	21208	21181	21153	21161	21142	21183	21188	21115		[illegible]	21164	21175	29
Inert Parts Wt.	2454	2478	2466	2429	2436	2433	2416	2435	2470	2419	2408	2422	2432		[illegible]	2486	2440	25
Nozzle Wt.	430	428	435	426	425	432	422	430	434	432	423	425	422		[illegible]	433	430	5
Grain Fraction	.8968	.8952	.8959	.8971	.8968	.8970	.8968	.8968	.8955	.8973	.8979	.8974	.8967		[illegible]	.8949	.8965	.0009

*Calculated

(1) Include nozzle and igniter
(2) C.G. Ref index is fwd face of chamber fwd thrust ring.
(3) Determined by subtracting the pre-cast chamber weight from the loaded motor (less nozzle and igniter) weight.
(4) Following Motor IIA-1 the grain configuration was changed, the insulation was changed and more insulation added resulting in a change in motor nominal wt values for II A-2 motor.
(5) Following Motor IIA-2 the grain configuration was changed by the addition of styrofoam fillets to the core, and the insulation design was optimized. This standardized the design for all subsequent motors and changed the nominal wt values for motor IIA-3 and all motors following IIA-3.
(6) Motors IIA-1, IIA-2 and IIA-3 not included.
(7) Corrected from 23521 previously reported. Previous value did not include weight of igniter and weatherseal.
(8) Nozzle to be installed.

Motor Weight Summary, Algol IIA

Figure 2



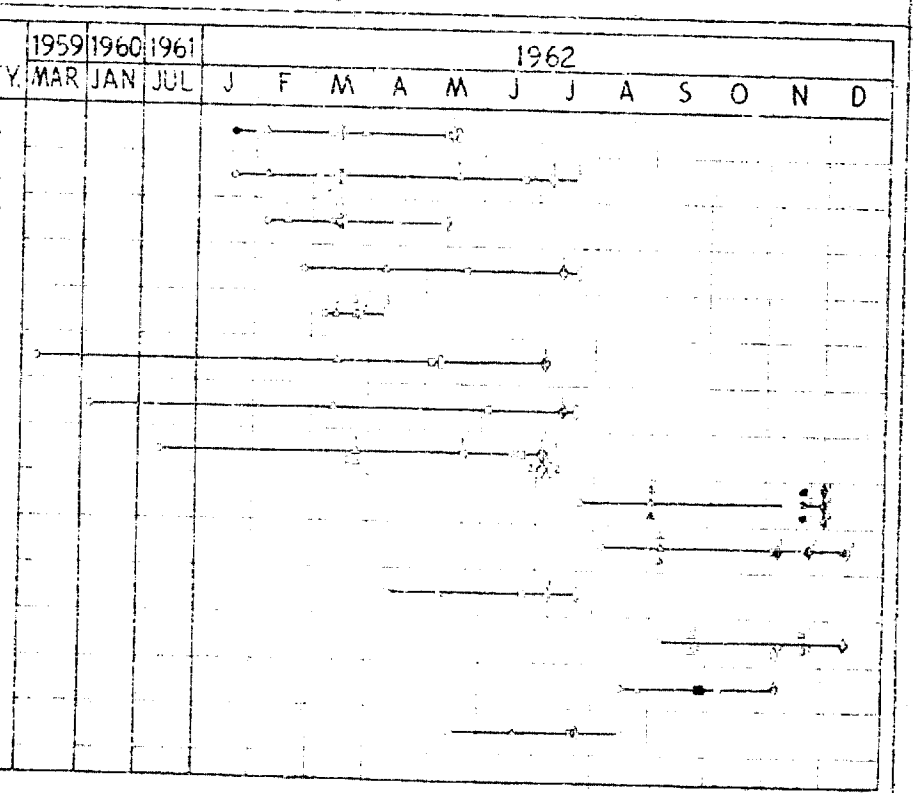
Squib Acceptance-Plan Flow Chart, Algol IIA

Figure 3

TOOLING SCHEDULE-ALGOL II A MOTOR

CONTRACT NAS1-1330

ITEM NO.	TOOL NO.	DESCRIPTION	QTY.
1.	T-422132	SOFT CORE ASSEMBLY	2
2.	T-422152	CASTING EQUIPMENT	2
3.	T-422163	HANDLING CART CORE	2
4.	T-422188	CURING STAND-TWO MOTORS	1
5.	T-422263	INSTALLATION TOOL-IGNITER	3
6.	T-404262	HORIZONTAL LIFTING BEAM	1
7.	T-420378	BELL EXTENSION	1
8.	T-421737	HANDLING RINGS	3
9.	T-422306	TRANSPORT CART-ALUMINUM CORE	3
10.	T-422305	CORE ASSEMBLY-ALUMINUM	3
11.	E-300044	HORIZONTAL TRAILER	1
12.	T-416147	CORE ASSEMBLY BRACKET	3
13.	T-416148	BREAKAWAY FIXTURE CORE	1
14.	T-422131	PAINT FIXTURE	1



○ DESIGN — COMP DATE ◎ IN FABRICATION ◻ DATE TO BE INSPECTED ◆ DRY RUN ◊ DATE REQUIRED

CHART NO. TP 8334
DATE 28 JUN '62

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Figure 4

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